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IN
ZOOLOGY
Vol. 8, Nos. 8 and 9, pp. 311-352, pls. 22-25 November 18, 1911

ON A SELF-CLOSING PLANKTON NET FOR HORIZONTAL TOWING

BY

CHARLES ATWOOD KOFOID

ON AN IMPROVED FORM OF SELF-CLOSING WATER-BUCKET FOR PLANKTON INVESTIGATIONS

BY

CHARLES ATWOOD KOFOID

BERKELEY
THE UNIVERSITY PRESS

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IN
ZOOLOGY

Vol. 8, No. 8, pp. 311-348, pls. 22-25 November 18, 1911

ON A SELF-CLOSING PLANKTON NET FOR HORIZONTAL TOWING

BY

CHARLES ATWOOD KOFOID

(Contribution from the Laboratory of the Marine Biological Association of San Diego)

A prime desideratum for marine exploration has long been a self-closing plankton net for horizontal towing. This type of apparatus is especially needed for the investigation of the vertical distribution of pelagic organisms, is indispensable for the detection and analysis of their vertical migrations, and is a necessity for the study of distribution and of migrations in stratified waters where abrupt changes in temperature, salinity, and plankton content may occur within a short vertical distance.

The evidence of such stratification brought to light by the investigations of the Biological Station at La Jolla (see McEwen, 1910) and the plan of this enterprise to conduct a systematic régime of work upon the plankton (see Ritter, 1905) have made necessary a survey of existing models of self-closing plankton nets, with the result that it seemed necessary that a net for horizontal towing would have to be devised especially for this work. A brief historical resumé will outline the development of this line of apparatus and also serve to indicate the limitations and defects which have been, or may be, attributed to the various patterns hitherto employed for submarine investigations of the plankton.

HISTORICAL DISCUSSION

The Sigsbee (1880) gravitating trap appears to be the first self-closing instrument devised for plankton collecting in deep water. It is a small sieve operating vertically, clamped upon

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the cable and lowered closed; released by messenger at the desired level, it slides down the cable to a buffer which stops and again closes it. It is held closed by its own weight. This apparatus can be used only in a vertical direction, is small, and any increase in size involves difficulties in its clamping to, and release from the cable. As constructed there is a possibility, readily obviated by a spring catch, of the surge of the vessel, or irregularities in heaving in the cable, temporarily opening the bottom of the trap. This apparatus was used by Agassiz (1888a) on the "Blake," but has not been generally adopted or developed. The recently devised vertical net of Buchanan-Wollaston (1911) is the nearest approach to it in working principle.

The protozoan trap of Cattaneo (1882), devised for collecting the bottom fauna of Lake Como, functions only upon striking a substratum. It is really a water-trap some of whose principles are developed in later patterns of water-buckets (see Kofoid, 1906).

The first plankton net for horizontal towing seems to have been devised by Pavesi (1883) for use in Italian lakes. It is lowered while open, and its lateral semicircular jaws are closed by a spring released by a messenger. This net is of frail construction, not adapted for deep-sea work. There is nothing to prevent its functioning as a filter, partially at least, during descent, and the closure is neither exact nor certain.

The closing-net devised in 1882 by Captain Palumbo of the "Vettor Pisani" Expedition described by Chierchia (1884, 1885, see also Richard, 1908) was so constructed that the pressure against the water during descent was expected to keep the net closed and that it would open upon ceasing to descend. The propeller mechanism of a Miller-Casella reversing thermometer was employed to close the net. This was placed above the net and released a weight whose pressure was expected to hold the net closed. Chierchia (1885) regards the closure as inadequate. and Chun's trials of a net of the Palumbo pattern led him to reject it as unsatisfactory. Agassiz (1892) has criticized it on the ground of incomplete closure and possibility of reopening during descent. The net of Imhof (1885) was never adequately described, while that of Turbyne (1885) was adapted to vertical

or oblique towing in shallow waters only, and was opened and closed (by constriction) with a special rope for the purpose. The two lines would inevitably become entangled in use at any considerable depth, and perfect closure would be difficult to secure and maintain.

Pouchet and Chabry (1887) describe a net, used (?) at Concarneau after experiments on the "Hirondelle" with the Chun net, which is an adaptation of the Pavesi model. Two heavy semicircular jaws turning on a vertical axis which traverses the mouth of the net are slipped down this axis by the action of messengers, a curved slot in the surface of the axis guiding each jaw through an opening and closing movement of 90°. Details as to messengers, trips, and control of the movement of the arms are wholly lacking in both the description and figures, and the further development of the model seems to have been abandoned.

Later the Prince of Monaco (1887) describes an improved form of closing-net made by Dumaige, the original of which he ascribes to de Guerne. Both the original de Guerne net and the improved form differ from the Pavesi net, upon which they also are modeled, in having a vertical axis bearing the coiled spring which traverses the opening of the net, and in being both opened and closed by messenger. The axis is an obstacle to some forms of organisms entering the net and it is evident that the closure cannot be complete in the nets as figured. No further use or improvements in this net seem to have been made in the later campaigns of the "Hirondelle" and her successors, and the author later (1889a) describes the closing action of the half-ring as inconstant and the closure as sometimes delayed till the net is removed from the water.

In the same paper (1887) a modified form of the Chun-Petersen net then in use by Professor Chun at the Naples Station is also described and figured. The modifications pertain to minor matters of the form of the spiral thread on the axle, the propeller, and the attachment of the net. The principles of operation by propeller and of vertical action remain unchanged.

The Chun-Petersen net described by Chun (1888, 1903) is a vertical net which is lowered closed, opened by the action of

a propeller, and, after a period of towing, is later closed by continued action of the propeller and the release of one set of connections between the net and the cable, and the transfer of its weight to another set, which closes the jaws. This net has been criticized by the Prince of Monaco (1889a), who regarded the action of the propeller as so uncertain that the depth at which the net functioned could not be established, since the surge of the ship, irregularities in heaving out and hauling in the cable, and entanglement of siphonophores and medusae upon the propeller would all tend to modify, or impede the releasing action of the propeller, and render uncertain the time and levels in which the net was in operation. He also regarded the closure as incomplete, a defect noted by Chun (1889) himself, which has, however, been remedied in later models of the net. Later Agassiz (1888b, 1892) criticizes the net on the grounds of its imperfect closure, and Hensen (1895) regards even the improved form as still defective. In any event some uncertainty as to the time and level at which any closing-net, which is actuated by a propeller, is really in operation, must always remain.

Hoyle's (1889) deep-sea towing net is built on a unique pattern for operation while towing with the cable in oblique position. The net is operated by messengers which release ropes attached to the hinged semicircles which constitute the rim of the net. The strain of towing is relied upon to keep the net closed both in descent, and, after closing, during ascent. It is obvious that irregularities in the tension upon the towing cable due to surge of the ship or changes in speed of reeling engine or ship will endanger the continuity and certainty of closure of the jaws of the net both during descent and ascent. This net does not seem to have been adopted elsewhere.

The next considerable step in advance was made by the Prince of Monaco's (1889a, 1889b, see also Marenzeller, 1891, and Richard, 1902, 1910) curtain net. This is built upon an entirely new principle and was adopted after partial tests at sea of the net of the Pavesi (1883) type as modified by de Guerne and later by Dumaige (see Monaco, 1887), and after tests of a net of the Chun-Petersen type. The net is devised for horizontal towing, at the end of a vertical cable. The cable with terminal

weights is first lowered to the desired level and then the net is slid down on the cable and the curtain across its square opening is withdrawn and rolled up as the net strikes the terminal weight. After towing, the net is closed by a messenger whose impact unrolls the curtain again across the opening. The amount of weight at the end of the cable can be readily increased for increased depths or greater speed in towing, so as to maintain a horizontal position of the net. The bag of the net itself is very short so as not to become entangled during descent with the closing apparatus or weights. This net in its operation on the "Hirondelle" and her successors has, according to all reports, functioned with accuracy and certainty. It was used also upon the "Pola" Expedition (see Mörth, 1892), but not with entire satisfaction. The rather complicated structure of this net and the great cost, over fifteen hundred francs, appear to have interfered with its general adoption. It may also be noted that in hauling in the net some pressure will be exerted through the upper side of the bag against the flexible curtain whose free lateral edges might be pushed outward with resulting loss of contents. Furthermore, there appears to be no device in the net, as constructed, for insuring positively that it is at the bottom and has been opened when the messenger strikes it and brings about a condition indicating closure. The net has also a minor disadvantage in having two vertical bars crossing the opening.

It is unfortunate that the closing net in process of perfection by Fol (1890) was never described.

An ingenious device for a closing-net to be opened and closed at any desired depth by the pressure of the sea-water is described by Viguer (1890) of the Algerian biological station. This net would be opened upon reaching the depth to which the pressure apparatus was adjusted and closed again upon leaving it. It does not appear that it was ever actually successfully constructed. It is obvious that it would be expensive to build and difficult to maintain in efficient working order.

A modification of the curtain net of the Prince of Monaco was used by Professor Th. Barrois (1892) in his exploration of Syrian lakes. He substituted for the silk curtain which closed

the net a sliding sheet of copper. The chains which controlled the movement of the curtain were also dispensed with. The net was otherwise opened and closed as in the original model, and is reported to have worked with certainty and to have given satisfactory results.

The Tanner self-closing net, first described by Agassiz (1892), and later, also in an improved form, by Tanner (1893, 1894), is designed for "intermediate towing," which in action is practically horizontal, since, by "veering and heaving in on the tow line" the desired depth may be maintained. The depth at which the net is operating is ascertained by the dredging quadrant. The net is lowered vertically while open and is then towed at the desired depth and closed by messenger after return of cable to the vertical position. The closure is by weights which draw a puckering string about the middle of the bag. The lower end will thus contain the catch made before closure. In the earlier model the closing weights worked on guy ropes running from the net ring to the terminal weight. In the later model two lateral brass pipes were substituted for the ropes and the weights slide down these. At the lower ends the pipes are attached to an apron or vane which is supposed to prevent the whirling of the net.

In the hands of Mr. Agassiz and Captain Tanner this net has given satisfactory results. The objections which may be urged against it are that (1) the successful operation in intermediate levels, i.e., while functioning as a horizontal net, requires considerable speed and introduces some uncertainty as to the level of its operation, (2) the net is open in descent and the vortex about its rim may introduce some animals into the net, (3) the open upper part of the bag of the net brings, during ascent, considerable pressure to bear upon the region of closure, tending to force the catch of the upper part of the bag into the lower. Another objection, applicable especially to the first model, is that the heavy weight attached to the tail of the net to keep the guy ropes supporting the closing weights in place, would tend to interfere with the mouth of the net taking a position of maximum exposure to the water entering the net, i.e., to keep it vertical, instead of oblique, during the horizontal

towing, and thus to reduce the relative amount of the catch as compared with that taken during the ascent of the net. This objection is less applicable to the improved models in which the only weight to the rear is that in the light pipe-frame for the closing weights.

The small horizontal closing-net of Frič and Vavra (1893) is of a simple type with two ropes, one for towing and a second for closure by constriction, obviously ill-adapted for work in deep water.

The idea of using the pressure of the water to open and close the net is embodied in the description given by De Livron (1893), Lieutenant of Marine in the Russian Navy, of an apparatus with a piston, set to begin movement under the desired pressure, that is, at the desired depth. The lids are connected with the piston and its first movement opens the net. It is closed again by the piston when it moves because of the increase or decrease of the pressure. No figures of the apparatus are given and there is no evidence that it was ever actually successfully operated.

The Giesbrecht (1893) self-closing net is devised for horizontal towing and is sent down closed, is opened by resistance of the water upon the two spreading wings, when towed horizontally, which releases the closing lever. It is closed by messenger. The four hinged sides of the square opening of the net spread open by their own weight upon release and closure is accomplished by their folding together again. In its original form the bag of the net is rather complicated and not readily cleaned and the system of opening not sufficiently under control. In operation at sea in rough weather or in deep water it would be impossible to determine with any certainty when the net really opened or to be positive that the closure was complete and continuous, since the net is held closed merely by its own weight. Furthermore, the vertical bar across the opening interferes with the capture of certain pelagic organisms. In a modified form (Richard, 1896) the net has been used somewhat extensively in connection with the explorations of the Prince of Monaco, apparently with satisfactory results.

Heincke (1894) describes a "Brut-netz" used at the Helgoland Station for taking fish-eggs and fry. It is anchored in a current to a float, being lowered open, till it floats out at the desired level. While in operation it is suspended by a line to the crowfoot running to the usual marginal ring. When withdrawn it is hauled in by a second line running to a second ring about one-third of the length of the net from its mouth. The terminal ring, as it falls, carries the upper part of the bag across the opening of the second ring and thus closes the net during descent, a principle later employed in the Marsh and Nansen closing-nets.

The Birge (1895) closing-net devised for limnological exploration is adapted only for vertical hauling. It is opened and closed by weights released by messenger. The lid is slid off horizontally from the top of the net in opening and returned in closing. As constructed, the net is cumbersome and ill-adapted to work at sea because of the numerous lines and dangling weights.

Hensen (1895) mentions a photograph of a Norwegian closing-net drawn by three cables and operated by propellers and clockwork, devised for exploration of currents, and evidently for horizontal towing. He unfortunately gives no clue to its origin and I have found no other reference to it in literature. It seems to have joined the procession of failures. Professor Gran writes me that he does not know the history of this net.

The Townsend (1896) closing-net is adapted to vertical hauling or to towing at the end of an oblique cable (intermediate towing). It is lowered open and closed by messenger. Closure is effected by release by messenger of a lever which shifts the weight of the net upon tow lines which close the semicircular jaws. A sliding weight upon the original tow lines tends to hold the jaws closed. The trip requires very careful adjustment of a bent spring to insure control of its operation and is liable to get out of order. Furthermore, the net open in descent is objectionable, and the system of closing is open to the criticism of uncertainty as to its continuity. The net has not been generally adopted for deep-sea work.

A folding-ring net for opening and closing by messenger

which "worked satisfactorily" in the experimental model but was not perfected for work at sea was also devised by Townsend. The trips of this net are of a better type than in the net just noted, but the means of maintenance of closure during descent and ascent are subject to criticism since closure depends upon the weight of the net upon the tow lines. Currents and irregularities in movement due to surge of the ship or irregularities in hoisting might lead to release of tension and gaping of the jaws.

A modified form of the Giesbrecht net has been devised by Richard (1896), who abandoned the horizontal pressure upon the wings as a means of opening the net and substituted the method employed in the curtain net of the Prince of Monaco, to wit, sliding the net down the cable and opening it by impact on the terminal weight. He also modified the trip for closing and hinged the horizontal vanes designed to keep the apparatus from whirling. Richard (1896) speaks well of the original model, but prefers the improved one because of certainty of closure. "C'est un instrument robuste, qui mérite, modifié, ou non, d'être employé de préférence à ceux qui ont été décrits jusqu' ici pour remplir le même but." See also Monaco (1902) and Richard (1900, 1902, 1910).

The closing-net of Lakowitz (1896) is designed for horizontal towing and is opened and closed by accessory lines which operate two hinged lids on the square opening of the net. The lids when closed are latched by spring catches. The closure is thus exact and continuous, but the accessory lines could not be adapted to work in deep water.

The closing-net designed by Cori (1897) operates in a horizontal position and is opened and closed by messenger. The opening of the net is rectangular with a rim of six straight pieces, long top and bottom pieces and jointed sides of two pieces each. The vertical sides are jointed in their centers and bend inward when the net is closed. The net is lowered closed with the lower horizontal margin raised against the upper one and the sides collapsed inward. The first messenger drops the lower bar and thus opens the mouth of the net, while the second drops the upper bar down upon the lower, folding the sides

inward again and thus closes the net. This net is simple, with an opening free from impeding bars, and the plan seems to be capable of adaptation to deep-sea work, by the addition of an automatic lock to hold the net firmly in place when closed and by the necessary strengthening of the frame to carry the weights needed below the mouth of the net. It would also need some adjustment of parts at the rim to make the closure absolutely complete and a supporting rod for the bag of the net to keep it from wrapping itself about trips and cable during descent. The general design is one meriting perfection and wider adoption.

In his investigations upon the plankton of Bodensee, Hofer (1896) used the horizontal net of the Cori (1897) model, which he states functioned with extraordinary certainty, the opening and closing of the net being distinctly noticeable on the cable, even when the net was at the depth of one hundred meters. He also adopted a net of the strangulation type towed by two ropes, the tow-line passing obliquely to the net and a second closing line vertically from the net to a life-preserver towed sixty meters behind the boat. This method is criticized by him as cumbersome.

Marsh's (1897) vertical closing-net is lowered open, closed by a messenger which releases the line which goes from the head of the crowfoot to the trip, and transfers the weight of the net to a constricting line about the middle of the bag. The upper part falls down and effectively prevents the entrance of any material during ascent after closure. The objections to this and all other nets of its pattern are (1) that it is lowered open and critical results are not obtainable since contamination is possible, as a result of the swirl about the open mouth during descent; and (2) the contents of the upper part of the bag where filtration is greatest may be lost in closing, a difficulty partially obviated in the Nansen net by an elongated non-filtering area at the head of the bag.

The Petersen (1898) closing-net is a modification of the Hensen plankton net, the only change being the addition of two hinged semicircular lids which are released by messenger and fall into closing position by their own weight. The net is lowered open and the lids are not locked after closing. Since

the filtering area of the silk bag normally exceeds the area of the orifice of the net and the upper cone of the net is of impervious canvas, there is no certainty that the irregularities in movement of the net after closure will not open the lids, spill out part of the catch, or even admit other organisms. This type of closing-net seems to have been first figured by Apstein (1906).

Fowler's (1898) "mid-water" tow-net is devised for vertical work, is sent down closed, and is opened and closed again by messengers. The net is suspended by two sets of chains to the "locking gear" or tripping apparatus at the end of the cable. The mouth of the net is rectangular with hinged jaws working on a central axis. When suspended by the closing chains the two jaws are held together by weight of the net, when suspended by the towing chains the jaws fall open by their own weight and the tension upon the net. This net was used extensively by Fowler in his investigations in the Faeroe Channel and Bay of Biscay and worked satisfactorily. It was also used on the "Valdivia" and "Siboga" expeditions (see Fowler, 1898, and Weber, 1902). The criticisms which might be passed upon it are perhaps more of a theoretical than of a practical nature. The large tripping apparatus and the bar and chains across the opening are undesirable as impeding the entrance of active or filamentous organisms. It also seems to the writer that the light weight of the net, upon which the certainty and continuity of closure wholly rest, is its weak point. The frame weighs, according to Fowler, only sixteen and one-half pounds and this would be reduced in sea-water to about fourteen pounds. The locking gear and chains weigh thirty-three pounds and have less area of resistance than the net and bag. It would seem possible that the surge of the ship and irregularities in heaving in the cable might lead to an intermittent gaping of the jaws of the net before opening or after closing, since the heavier locking gear would tend to respond more readily than the lighter net and bag to oscillations of the cable. With an even tension on the towing chains there is no chance for the resistance of filtration to spread the jaws, but the instant the chains are slackened their weight at the ends of the closing levers would tend to open

the net and permit the spreading effect of the resistance of the filtering surface. It is probable that the chances of such an intermittent gaping under normal operation of the net are remote, but one would be more certain of the accuracy of the results if this remote possibility were removed.

The Cori net is criticized by Burckhardt (1900), who used a model constructed by Hofer (1896), double the size of the original Cori pattern, on the ground that the closure is not complete on account of the lack of attachment of the bag at the six hinges and the insufficiency of the vertical closing plate across the closed mouth of the net. He also found the net failing to function because the net or the wire became entangled in the trips, possibly due to lack of experience in handling the apparatus. He also expresses uncertainty as to the control of the opening of the net and of the level at which it operates, and finally calls attention to the practical difficulty of determining the distance traversed by the net. Burckhardt is a proponent of the vertical net and has quite fully stated the difficulties of the horizontal net. They can, however, be obviated in the main: the closure perfected by slight changes in construction, the net bag controlled by a supporting arm, the messengers adjusted in weight to give certain action on the trips, and the horizontal course of the net improved by increase in weight of the frame and adjustment of the speed of towing. The determination of the length of the haul presents the greatest practical difficulty of the defects he enumerates.

The Burckhardt (1900) vertical closing-net has a contracted conical head after the Hensen model with circular lid hinged at one side, opened and closed by weights released by a trip of the Cori pattern. The trip is operated by messengers. Burckhardt experimented with the net, sinking it open, immediately closing it before raising it, and found that the net "ganz leer blieb." He therefore rearranged the connections of the net and trips so that the first trip closed the net and the second released the head of the net so that it fell to one side as in the Nansen net. This decreased the resistance in hauling in and hastened the operation of collecting. The objections to a net of this pattern, for work at sea, are the dangling weights, and the resist-

ance of the impervious head of the net in hauling in. Burckhardt's experimental proof that the net remains empty when lowered open may be valid in quiet waters, but would be less probable in a net subject to the surge of a ship. In any event, with the net open in descent, a certain element of uncertainty is always present which is entirely eliminated in the net closed in descent.

The Voigt (1902) horizontal closing-net is sent down closed, and opened and closed again by concentric messengers. The first releases the oblique door which falls to a horizontal position by its own weight. The second releases the square frame or rim of the net, which also falls into a horizontal position upon the door and thus closes the mouth of the net again. The weight of the frame alone is depended upon to keep the net closed. The net is simple and apparently effective. For marine work the no less than five vertical bars of the frame, as well as the considerable horizontal parts, offer an impediment to entering plankton of the larger sorts. A self-locking device on both the door and rim would be necessary for use at sea to keep these parts in place. The model is one deserving further elaboration.

In the explorations of the "Puritan" off Capri, Lo Bianco (1903) used a closing-net of very large size, planned and built in the Krupp works at Essen. The net is now at the Naples Station. It is constructed in the main after the pattern of the Chun-Petersen net, for vertical work, with hinged semicircular jaws, opened by and closed by messengers. Its operation was satisfactory.

The Garstang closing-net operated at the Plymouth Station since 1903 is planned for horizontal towing, with diagonally suspended quadrilateral rim as in the Giesbrecht net. It is opened and closed by messengers. It is very compact, all of the parts being included in the large, cylindrical, vertical axis, and the hinged frame sliding upon it. It is rather light for work at sea with a vertical cable, and the trips are not always successfully discharged by the messengers. I have not found a description of this net.

The "Scotia" closing-net devised by Bruce (1904) is essentially like the "Nansen" net, being available only for vertical

work and having a messenger which cuts loose the tow line and transfers the weight to a puckering line which closes the net some distance below the opening. The trip is that of the Scottish reversing thermometer frame. The objections to the net are practically the same as those to the Nansen net, with the addition that the trip does not appear to be sufficiently guarded against miscarriage.

The Nansen net has been in use for a number of years by the various bureaus of the International Commission for the Investigation of the Sea, but seems not to have been described in detail by any one. Figures and an account of its operation will be found in the papers of Gran (1905) and Herdman (1908). It is a vertical net, lowered open, drawn up for the desired interval and closed by messenger which releases the crowfoot above the bag transfering the weight to a strangulation cord. The net is simple, easily operated, and effective. It has the defect of being lowered open, and thus admits the possibility of contamination. For mass work it is to be highly commended, but its results are not critical.

The Buchanan-Wollaston (1911) vertical net functions mouth downward during descent only, and closes by a puckering string tightened by a weight sliding on the standards which form the frame. This net has the unique advantage, among vertical nets, that the column of water which it filters is undisturbed by cable, lines, or bars of any sort as it enters the net. The addition of a double trip and some method of sending down the net closed to any desired level, before opening it by messenger, would convert this into a very valuable type of vertical self-closing net.

A NEW TYPE OF HORIZONTAL CLOSING-NET

The desiderata to be sought in a net for this kind of towing are (1) a net closed during descent, (2) a method of opening and closing entirely under control of the operator and wholly free from interference by external conditions, such as irregularities in unreeling or reeling in the cable, or by oscillations due to surge of the ship, thus insuring continuity of closure both prior to opening and subsequent to closing, (3) perfect closure

in all respects so that no plankton can enter while the net is closed, a feature obviously requiring finer adjustment in nets using the finest (no. 20) silks than in those with bags of coarser mesh, (4) sufficient weight to insure a measurable control of level of operation in towing, and (5) an orifice free from impeding structures. These desiderata have been secured in the net here described (pls. 22 to 25) which is the result of many tentative designs and is an improved form of the model first constructed.

ACKNOWLEDGMENTS

The general type of net adopted is one suggested to me in correspondence by my friend, Dr. G. Herbert Fowler, of Aspley Guise, Bedfordshire, England, of the "Research" Expedition. I am greatly indebted to the San Diego Marine Biological Association, and its scientific director, Professor W. E. Ritter, for their continued interest in the project, and for the aid which carried it through the expensive experimental stage. In the original designing of the net I have had the valuable aid of Mr. Val Arntzen, expert mechanician at the University of California, and in the final designing, pattern-making, and solution of mechanical difficulties of construction, I have had the invaluable assistance of Mr. Robert Baker of the Baker Machine Company of San Diego. I am also indebted to Mr. E. L. Michael of the Biological Station at La Jolla, who has had considerable experience in the use of the first model of the net, for suggestions and criticisms.

The net here described was first built in 1908. In 1909–10 a second and improved model was constructed for the Prince of Monaco for the exhibit of oceanographic instruments in the Musée Océanographique at Monaco, Principauté de Monaco. The description which follows pertains, in the main, to this net.

GENERAL DESCRIPTION

The net in general plan is a jointed-ring net with circular opening, operated by messengers which release the semicircular laterally hinged jaws actuated by springs. The frame is very heavy and its weight may be increased by the addition of special weights below. The trips are held in place by springs. The

bag is supported in a horizontal position and the net itself is easily removed from the frame for emptying the catches.

The bag of the net (pls. 22 and 23) is a simple cone of silk bolting cloth held in a horizontal position, with detachable bucket of brass at the truncated tip and head-piece of heavy linen. The jaws which form the rim about the opening of the net stand in a vertical plane when open. The two jaws (*up. j.* and *l. j.*, pl. 24, fig. 5) are of semicircular form and are bevelled so as to close tightly on the bevelled surfaces (*bev.*) and rotate on a horizontal axle (*ax.*) which is enclosed in each of the hubs in the frame.

THE NET FRAME

The frame (pls. 22 and 23) is a massive casting of phosphor-bronze, of circular form with enlargements at the horizontal axis for the reception of the hubs of the jaws of the net. It widens on the lower edge to a square foot which bears a recessed groove for the reception of the accessory weight. The upper end of the frame is expanded into a round head-piece or pedestal from which project the pins of the trips and within which their mechanism is protected. Its rear face (pl. 23, fig. 4) bears a slotted lug (*lug*, pl. 25, fig. 15) in which the rods supporting the net (*n. sup.*) and accumulator support (*acc. sup.*) are hinged. Between the four projections upon the frame its outer surface bears a low rib, so that in cross-section it is low T-shaped, to insure rigidity when heavy weights are attached below. The front of each recessed chamber which receives the hub is closed by a hinged door (*d.*, pl. 24, fig. 6, compare also figs. 3 and 4) locked in place by hinged thumb-bolt (*th. b.*) which binds the bearing (*bear.*) on the inner concave face of the door against the machined outer surface of the cylindrical hub (*hub*) of the jaw of the net, and thus holds it rigidly in place, but allows freedom of rotation.

The steel dredging cable (*c.*, pl. 25, fig. 15), a $\frac{3}{8}$ inch plow-steel cable on the "Alexander Agassiz," with terminal eye adapted to all types of deep-sea apparatus, emerges from the vertical axis of the net. The perfect balance of the net in a vertical position is regulated in part by the lower flatiron-shaped

weight which can be slipped to any desired position in front-to-rear direction and secured there by the set-screw above it (pl. 23, fig. 4.). The parts in the right-to-left plane are structurally balanced in the main. The cable is passed into the position in the axis of the head-piece through a narrow cable slot (*c. sl.*, pl. 25, fig. 15) which is closed again by a close-fitting wedge or slot filler (*sl. fil.*) held securely in place by a pinto set screw (*s. scr.*) whose head projects laterally slightly beyond the margin of the pedestal (pl. 23, fig. 3). A stout steel cable bolt (*c. b.*), 2.5 by 24 cm., is passed from the side of the pedestal through the eye of the cable and secured in place by a winged thumb-bolt (*th. b.*[1]). The end of the cable bolt bears a circular opening (*op.*) for withdrawing it, when the thumb-bolt is released. When the bolt is free of the cable the thumb-bolt falls in the second position (*th. b.*[2]) after the fashion of a door bolt, and the cable bolt cannot be entirely withdrawn.

THE CLOSING MECHANISM

The closing mechanism consists of the two hinged jaws at the mouth of the net which swing forwards and downwards, the tripping apparatus in the head-piece, and the two messengers which open and close the net. The two hinged jaws (pl. 24, fig. 5) are semicircular phosphor-bronze castings which together complete a circle 37 cm. in inside diameter. Upon either side, each passes into a cylindrical hub (*hub.*, pl. 24, fig. 6, see also figures 5 and 10) 82 mm. long and 82 mm. in diameter. Each hub consists of three main regions, two of which (2 and 3) are structurally parts of the jaws; (1) the central axle (*ax.*, pl. 24, fig. 5), (2) the inner cylinder (*in. cyl.*), and (3) the outer cylinder (*out. cyl.*).

The central axis consists of a shaft 82 mm. long and 25 mm. in diameter whose inner end is bored and threaded for the screw (*sc.*) which holds the fixed pulley (*pul.*) against the inner face of the jaws and holds the axle (*ax.*) within the inner cylinder (*in. cyl.*). The outer end of the axle is a cylindrical head (*hd.*) 27 mm. long and 50 mm. in diameter with a cubical socket (*sock.*, pl. 24, figs. 5, 6 and 9) in the axis, 17 mm. square and 8 mm.

deep, for insertion of the key used in setting the coiled spring. The side of the cylindrical head is bored with twelve equidistant holes, 7 mm. in diameter, for the set screw (pl. 23, fig. 4; *s. scr.*, pl. 25, fig. 6) which holds the axis (*ax.*) in place when the spring is set. Wound around the shaft is a coiled spring (*r. coil sp.* and *l. coil sp.*) of heavy steel wire which makes about twelve turns around the shaft and has its inner and outer ends fixed respectively in the end of the jaw and in the head of the axis. Surrounding the shaft is a narrow chamber (*sp. ch.*), 8 mm. wide, in which the coiled spring, whose wire is 4 mm. in diameter, has some room in which to come and go, as the tension is changed. The outer wall of this chamber is formed by the inner cylinder (*in. cyl.*). Between the head (*hd.*) of the axis and this chamber for the spring and resting against the outer ends of the inner and outer cylinders, is a circular washer (*w.*) 82 mm. in diameter, 2 mm. thick, with central orifice 25 mm. in diameter.

The inner cylinder is 60 mm. in outside diameter, 82 mm. in length, has a wall 10 mm. thick, and central opening 39 mm. in diameter. The cylinder is continuous on the right side (of the figure) with the lower jaw and on the left side with the upper, that is, each inner cylinder is a part of a different jaw. From this method of construction it follows that the lower jaw is actuated by the spring of the right side (of figure) and the upper one by that of the left.

The outer cylinder (*out. cyl.*) is 82 mm. long and 82 mm. in diameter, with wall 10 mm. thick, and central opening 60 mm. in diameter. This cylinder is structurally continuous upon the right side (of figure) with the upper jaw, and on the left with the lower. The relations of the inner (*in. cyl.*) and outer (*out. cyl.*) cylinders respectively to the lower (*l. j.*) and upper (*up. j.*) jaws respectively are clearly shown in the views looking from the center of the opening of the net toward the hub, with the pulleys (*pul.*, pl. 24, figs. 7, 8) removed. With this method of construction it will be seen that the outer cylinder is perfectly free to turn around the inner cylinder between the outer washer (*w.*) which is held by the outer terminal of the coiled spring to the head (*hd.*) of the axis (*ax.*), and the inner pulley (*pul.*)

which is fastened by two small screws (*s.'*) to the flat inner end of the hub. The impelling force, however, for the movement of the outer cylinder comes in either jaw from the coiled spring in the hub opposite to the cylinder in question.

The pulley (*pul.*, pl. 24, fig. 5) is 77 mm. in diameter and 14 mm. thick with an asymmetrical groove 13 mm. deep. It serves to carry the elastic string which binds the adjacent margin of the net to the hub (*el.*, pl. 24, fig. 5; pl. 23, fig. 4). It is obvious from a comparison of figures 1 to 4 (pls. 22 and 23) that the margin of the net adjacent to the hinge, when the net is closed, encircles nearly the whole of the pulley, except only the part included in the width of the closed jaws, while in the open net (pl. 23, fig. 4) it is compressed to less than one-half of the circumference. The elastic tie-string (*el.*) passes around in the groove of the pulley and through a fold in the margin of the cloth head-piece of the net of a length sufficient to stretch over the necessary part of the pulley when the net is closed. This insures a plankton-tight junction of the net and its rim in this critical part of the apparatus.

The jaws proper are semicircular, flattening to rectilinear as they approach the hub. They (pl. 25, figs. 12, 13) are 40 mm. wide, 14 mm. thick at the base (*b.*), and 5 mm. on the square lip (*l.*). For a distance of 30 mm. back from the lip the surface of each is beveled (*bev.*) so that when the jaws are closed the two beveled surfaces are in immediate contact to the shoulders (*sh.*), thus insuring plankton-tight closure.

The structure of the trips ($tr.^1$ and $tr.^2$, pl. 24, fig. 9 and pl. 25, fig. 15) is simple. There are two, the one nearer the axis ($tr.^1$) being operated by the first messenger and the outer one ($tr.^2$) by the second. Each is located in a separate vertical trip chamber (*tr. ch.*) in the head-piece of the frame and consists of a shaft (*shaft*) about which is a coiled spring (*c. sp.*) which draws the clutch ($cl.^1$ or $cl.^2$) on the lower end of the shaft firmly up against the projecting hook of the rim of the jaw of the net ($hk.^1$ or $hk.^2$, pl. 24, fig. 9). These lugs are hooked and hold the jaws firmly in place. Each messenger strikes not only the trip but a second pin ($buf.^1$, $buf.^2$) on the opposite

side of the cable from the trip. This stop is adjustable and absorbs the shock of the messenger as soon as the trip is driven down sufficiently to release the jaw of the net.

The messengers are of two distinct types. The first messenger (pl. 22, fig. 1) is cylindrical, about 9 by 11.5 cm. and weighs about 4 kilos. Its diameter is just sufficient to strike the pin of the trip which releases the lower jaw and thus opens the net (pl. 22, fig. 2). The second messenger is provided with four spreading arched arms which carry a distal ring which drops over the first messenger and strikes the trip which releases the upper jaw and closes the net (pl. 23, fig. 3). Its total length is 30 cm. and greatest diameter 15 cm. and its weight about 8 kilos. Both messengers are made in halves which may be lashed together about the cable. The first messenger requires but a single lashing, the second two, one in each of the groves at each end (pl. 23, fig. 3). The greater length of the second messenger not only provides for overriding the first but it also tends to obviate anything but a square blow upon the tripping pins. The messengers may be lined with Babbitt metal to take up wear, as in the Arntzen detachable messengers used on my (1906) self-closing water-bucket, if desired.

THE NET AND PLANKTON BUCKET

The net proper is a simple conical bag of any desired stuff, preferably of silk bolting-cloth, with head-piece and bucket band of butcher's linen. The bag is fastened to the jaws by brass strips or closing bands (*cl. bd.*, pl. 25, fig. 13) held in place by numerous screws set into the inner face of the jaws. In the case of the finer silks, such as nos. 12 to 20, it is important to make the bag as long as possible, up to 2 meters.

To keep the bag from becoming entangled in the tripping device or about the cable, a supporting rod (*n. sup.*, pl. 25, fig. 15) 1.5 to 2 meters long, made in three sections, with distal end curved downwards (pl. 23, fig. 4) is attached to the rear of the head-piece of the frame. It carries a coiled spring at its outer end which connects it with the bucket which in turn is supported by a wire hook to the rod above it. The proximal end of this

supporting rod works on an axle suported in a slotted lug (*lug*, pl. 25, fig. 15) on the rear face of the head-piece of the frame (pl. 23, fig. 4) and can thus be bent downward during ascent of the net and upward during descent. This makes possible a more rapid heaving out or in of the net by reducing the area of exposure of the bag and tends to protect the catch during the handling of the net. As shown (pl. 23, fig. 4) the basal casting into which this rod is seated also carries a short rod (*acc. sup.*) curved upward, with two accumulator springs. During descent the basal casting in the slotted lug rests firmly against a shoulder or cushion (*cush.*, pl. 25, fig. 15).

The bucket is attached at the end of the net support (pl. 23, fig. 4) whose distal end is bent downward to the level of the bucket. Between the bucket and the tip of the carrier is a coiled spring which affords play to the net in the horizontal direction as the jaws open and close. The bucket bears two rings on one side for attachment by wire hooks (but one in figure) to the supporting rod above.

The bucket (pl. 25, fig. 16) is made from spring brass tubing 10 cm. in diameter. Its total length is 12.5 cm. It consists of a head-piece (*hd. p.*) which is encircled by a net clamp (*n. cl.*) which binds the linen bucket bands at the lower end of the bag to the top of the bucket. The clamp is a narrow band of spring brass bearing two flanges (*fl.*) drawn together by a small bolt. The head-piece is threaded on its inner face and the remainder of the bucket may be unscrewed from it for removal of the catch, without releasing the net from the clamp. The detachable part is a plain cylinder with dished bottom formed of a casting sweated into place with central outlet terminating in a drip-point (*dr. pt.*) below. The outlet is closed by a removable plug (*pl.*) of brass, ground in emery to fit closely and terminating above in a shaft with a ring above the level of the top of the bucket. This can easily be found and the plug removed or replaced through the silk bag without opening the net if desired, and the contents of the bag removed without detaching the bucket.

On one side of the bucket there is a circular window 4 cm. in

diameter and 1 cm. in height at lowest elevation with wire at its lip. Over this wire a silk window (*s. w.*) is stretched tightly and tied in place by a string (*str.*) behind the wire. This window affords sufficient filtration surface to reduce an ordinary catch to a volume readily contained by the detachable part of the bucket, and, when worn, the silk is readily replaced.

The weight (pl. 23, figs. 3 and 4) is flatiron-shaped, with pointed end anterior, to reduce resistance in towing. It serves as a foot for the net in landing on shipboard and may be removed easily if not needed, as in shallow waters. Its weight is 40 kilos, and it is made of cast iron. The spreading flange on its upper surface fits into the recessed groove on the under surface of the foot of the frame. It may be similarly grooved for a second weight on its under face if desired.

The total weight of the first model constructed, which differed from the one here described principally in certain minor details of construction and in the form of the frame and its weight, was over 125 kilos. The present model without weight or messengers weighs 70 kilos, with messengers 82 kilos. The cost of the improved model, which necessarily included some experimental work, and new patterns in large part, was three hundred and twenty dollars, complete with messengers, silk net and bucket. The apparatus was made by the Baker Machine Company of San Diego, California.

METHOD OF OPERATION

The setting up of the net for use is accomplished by fastening the silk bag in place with the inner brass bands and tying the closing strings around the pulleys. The supporting rod is adjusted to the bucket and the weight slipped into the foot. The springs are then adjusted to the proper degree of tension to insure closure on release by the trips. The adjustment is made by a square headed key which is inserted in the aperture at the end of the hub and fitted into the recess (*sock.*, pl. 24, fig. 9) at the end of this axis (*ax.*, pl. 24, fig. 5). The set screw at the rear of the hub (*s. scr.*, pl. 24, fig. 6; pl. 23, fig. 4) being released, the spring is wound up and the axis secured in the desired place by screwing in the set screws. It has been found empirically that

the springs, when set for satisfactory action in the air or surface waters, may not function as desired in one hundred fathoms or more. A number of variables enter into the problem of adjustment, such as resistance of the water, temperature, pressure, the mesh and tension of the net, and the depth. It is possible, however, with a given set of springs to adjust each coil so that the jaw which it controls will certainly function at any desired depth. This capacity for adjustment renders the net adaptable to messengers of different weights and to operation in different depths. In practice it has been found advisable in determining the proper tension to set the springs for operation in the air and then to slightly increase the tension little by little till the trips are properly released in the desired depth. The number of turns of the key for the tension demanded can then be made a matter of record and the given tension may thereafter be employed whenever the net is sent down to that depth.

The cable is then inserted in the head of the net, the cable slot closed, the net hoisted on the cable, and the weight upon the foot locked in place by the set screw so that the net is well balanced, the jaws are both raised in the upper position (pl. 22, fig. 1) and grasped by the clutches of the trips. The net is then ready for descent.

When it has been lowered to the desired level the first messenger is sent down, care being taken that the cable is in a vertical position. This drops the lower jaw to the lower position (pl. 22, fig. 2, and pl. 23, fig. 4) against the ledge in the lower arc of the frame (pl. 22, fig. 1) and opens the net. The vessel is then put in motion along the desired course and the net is in operation in a horizontal position at approximately the depth to which it was sent down.

I know of no satisfactory way of determining absolutely the precise depth at which this or any other piece of towed deep-sea apparatus functions. This depth is a resultant of a number of variables such as the speed of the vessel, force and direction of currents, resistance of the net and cable, the weight of the apparatus, the mesh in the bag, the quantity of the catch which may increase resistance by clogging, etc., etc. The determination of the depth of the apparatus by use of the dredging quadrant

(see Tanner, 1894) seems to be subject to increasing error as the depth is increased. Repeated instances occur in practice (see Fowler, 1898) in which bottom has been struck by apparatus when the dredging quadrant indicated that it should be some distance above the bottom. Giesbrecht (1893), as a result of experiments in aquaria with miniature apparatus, has arrived at the conclusion that much of the curvature, at least under certain conditions of strain, may occur in the upper part of the cable and the lower end be more and more approximated to the perpendicular.

In any event it is possible with the net here described, suspended by a 3/8-inch plow-steel cable, to a depth of 550 fathoms, to tow slowly with the visible part of the cable in an almost vertical position. Even with greater speed and some obliquity of the cable it is possible to reduce the vertical component of the path of the net far below that which is unavoidable in all vertical closing nets and perhaps, because of its greater weight, to reduce that hitherto obtainable in other types of horizontal nets.

When the towing is completed and the cable is again perpendicular the second messenger is sent down and releases the upper jaw which falls to the lower position, is held firmly against the lower jaw by the spring, and thus closes the net (pl. 23, fig. 3). In the original design spring-catches were used to hold the jaws firmly shut after closure. It has been found in practice that the closing secured by springs is adequate and constant. The cable is then reeled in, the spring in the supporting apparatus permitting the bucket to drop downward and thus tending to concentrate the catch towards the lower end of the net during ascent. Upon arrival on deck the rim of the net is released by unscrewing the thumb-nuts on the doors to chambers containing the hubs and dropping the doors downward (pl. 23, fig. 3). The set screws at the rear of the hubs are released and the net is lifted from the frame, its sides rinsed down to concentrate all the catch in the bucket, which is then removed. The net may be quickly returned to position for a second descent, by replacing the hubs, closing the gates, suspending the bucket and setting the spring.

This net has been used extensively in the form of the older model since the summer of 1908 (see Esterly, 1911a, b, and

Michael, 1911) with very satisfactory results in depths of 5 to 550 fathoms in explorations at sea in the Pacific off San Diego in the "Alexander Agassiz," a vessel of twenty tons, seventy feet in length.

The main objection to the net has been its great weight, a difficulty partly removed in the somewhat lighter model here described. The determination of the tension of the springs for closure at given depths has taken some time, but when once determined empirically for certain intervals the tensions for intermediate depths may be approximated without trial.

The net, especially with the finer grades of silk in the bag, is not devised for rapid towing, nor for large, actively moving animals such as the larger fishes and cephalopods. It does, however, take the very alert and actively moving *Sagitta* in large numbers and its catches in general exhibit a wide range of plankton forms from *Salpa,* Schizopoda and other plankton crustaceans, to the smaller forms. It should be possible to construct a net on this plan with large orifice with a bag of coarse mesh for the larger and more active forms. Such a net would have the advantage of an entire absence of all disturbing bars, ropes, cables, etc., in front of the opening.

The advantages which the net here described possesses over other models devised for deep-sea work are as follows:

1. A method of opening the net and closing it again at any desired level in the sea under complete control of the operator and free from interference by outside conditions.

2. Perfect and continuous closure of the net during descent and ascent of the apparatus, completely preventing the entrance of organisms except when the net is opened by the operator and preventing their escape after the net is closed.

3. The possibility of horizontal towing which makes feasible the more precise exploration of stratified waters, and the vertical migrations of pelagic organisms.

4. An opening free from interfering structures which tend to ward off the more active pelagic animals.

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Transmitted October 2, 1911.

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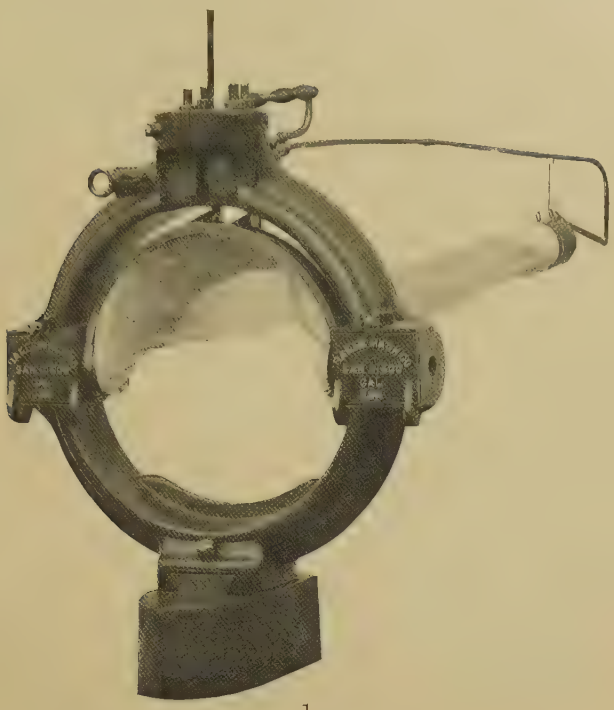
EXPLANATION OF PLATES

PLATE 22

Fig. 1. Front view of self-closing horizontal towing net. The net is set for descent, with both jaws in the upper position.

Fig. 2. Same view with net open, ready for towing. The first messenger rests upon the inner trip which has released the lower jaw and allowed it to fall to the lower position.



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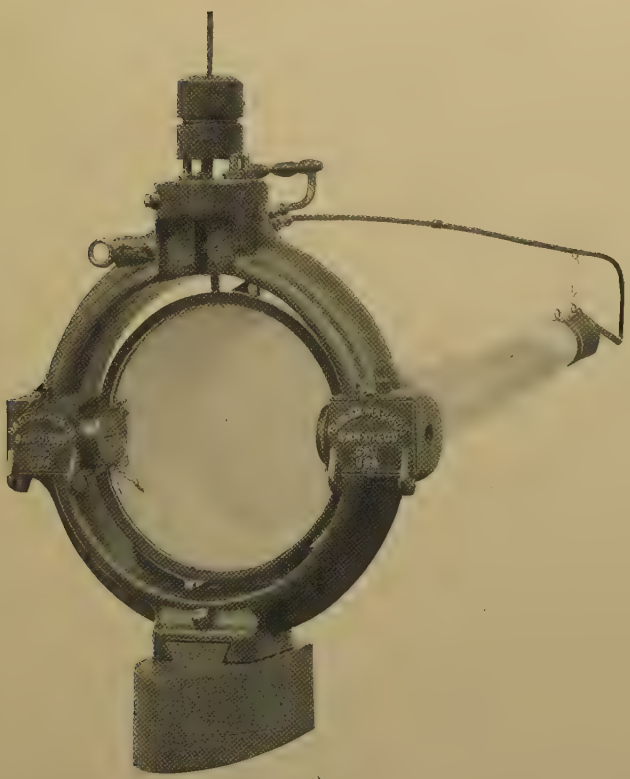

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PLATE 23

Fig. 3. Front view of net after closure. The second messenger rests upon the outer trip which released the upper jaw and allowed it to fall down against the lower one, thus closing the net. The thumb-nuts to the doors of the chambers containing the hubs have been released and the doors dropped down, exposing the hubs. The clutches of the trips project downward from the upper arc of the frame.

Fig. 4. Side view of net opened for towing. Note the set screw at rear of horizontal axis for holding spring in tension, and double acting accumulator springs at the rear of the head of the frame.

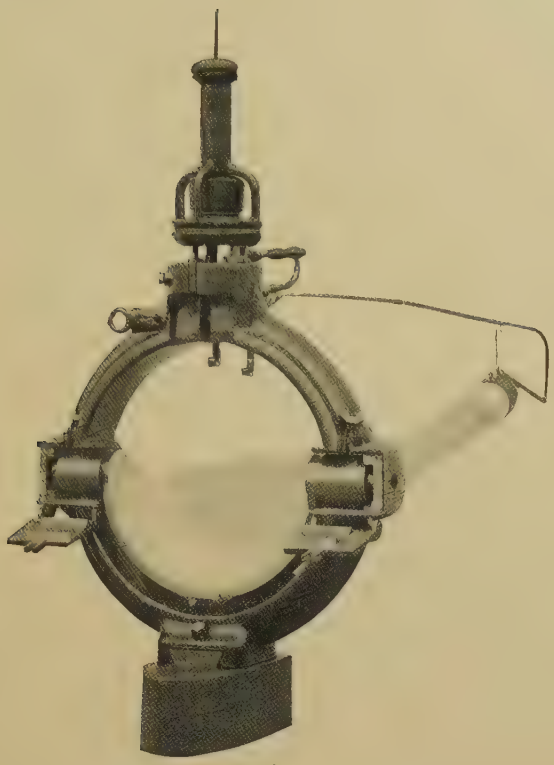

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PLATE 24

Fig. 5. Metal rim of net with jaws open, showing the hubs, at the side and the axle upon which they turn, in section. × ½.

Fig. 6. Section through lateral box at end of the hub showing relations of axle (*ax.*), hub, door (*d.*), and set screw (*s. sc.*). × ½.

Fig. 7. Face view of inner end of left hub showing relations of jaws and cylinders after removal of the pulley. × ½.

Fig. 8. The same of right hub. × ½.

Fig. 9. Section through head of the frame showing trips in place and both jaws locked as in the net when closed ready for descent. The position of the first (inner) trip is indicated by dotted lines. Rear lug for net carrier not shown. × ¼.

Fig. 10. Surface view of right hub. × ½.

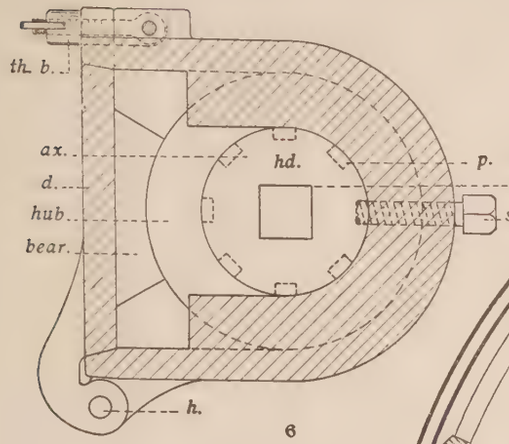
Fig. 11. View of outer end of hub. × ½.

Fig. 12. Radial section of upper jaw, showing method of attaching net. × ½.

Fig. 13. Same of lower jaw. × ½.

ABBREVIATIONS

ax.—axle.
b.—base of jaw.
bear.—bearing of hub.
bev.—bevel on face of jaw.
buf.—buffer.
c. sp.—coiled spring of trips.
cl.[1] *cl.*[2]—clutches of first and second trips.
cl. bd.—clamping band for net.
d.—door to hub chamber.
el.—elastic band for net at hinge.
h.—hinge of door.
hd.—head of axle.
hk.[1], *hk.*[2]—hooks of lower and upper jaws.
hub—hub of net.
in. cyl.—inner cylinder of net.
l.—lip of jaw.
l. coil. sp.—left coiled spring.
l. j.—lower jaw.
marg. cd.—marginal cord of net.
n.—net.
out. cyl.—outer cylinder of hub.
p.—pit for set screw.
pul.—pulley for elastic at hinge.
r. coil. sp.—right coiled spring.
s.—screw into axle.
s.'—screws for pulley.
s. scr.—set screw.
sh.—shoulder of jaw.
shaft—shaft of trip.
sock.—socket for wrench.
th. b.—thumb-bolt.
tr.[1], *tr.*[2]—first and second trips.
tr. ch.—trip chamber in head of frame.
tr. sp.—trip spring.
up. j.—upper jaw.



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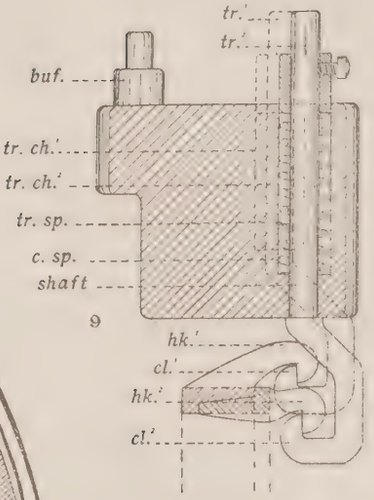

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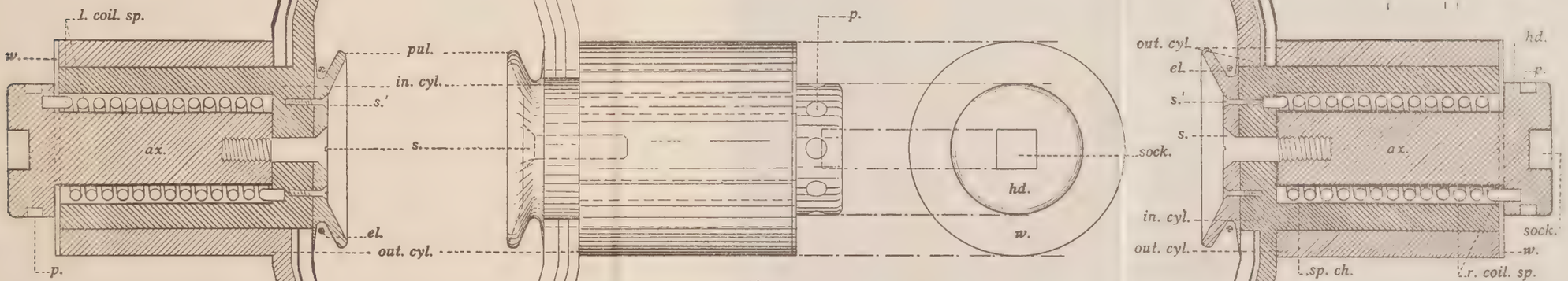

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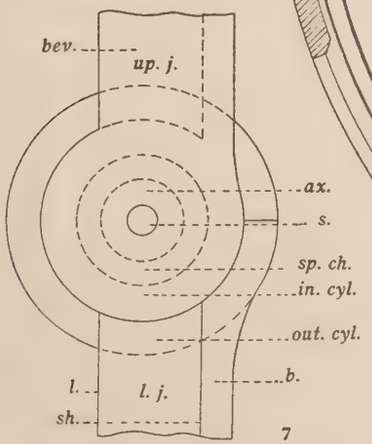

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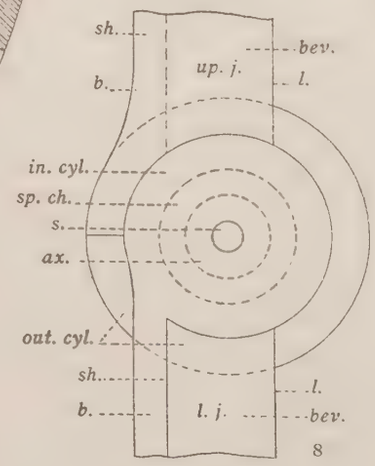

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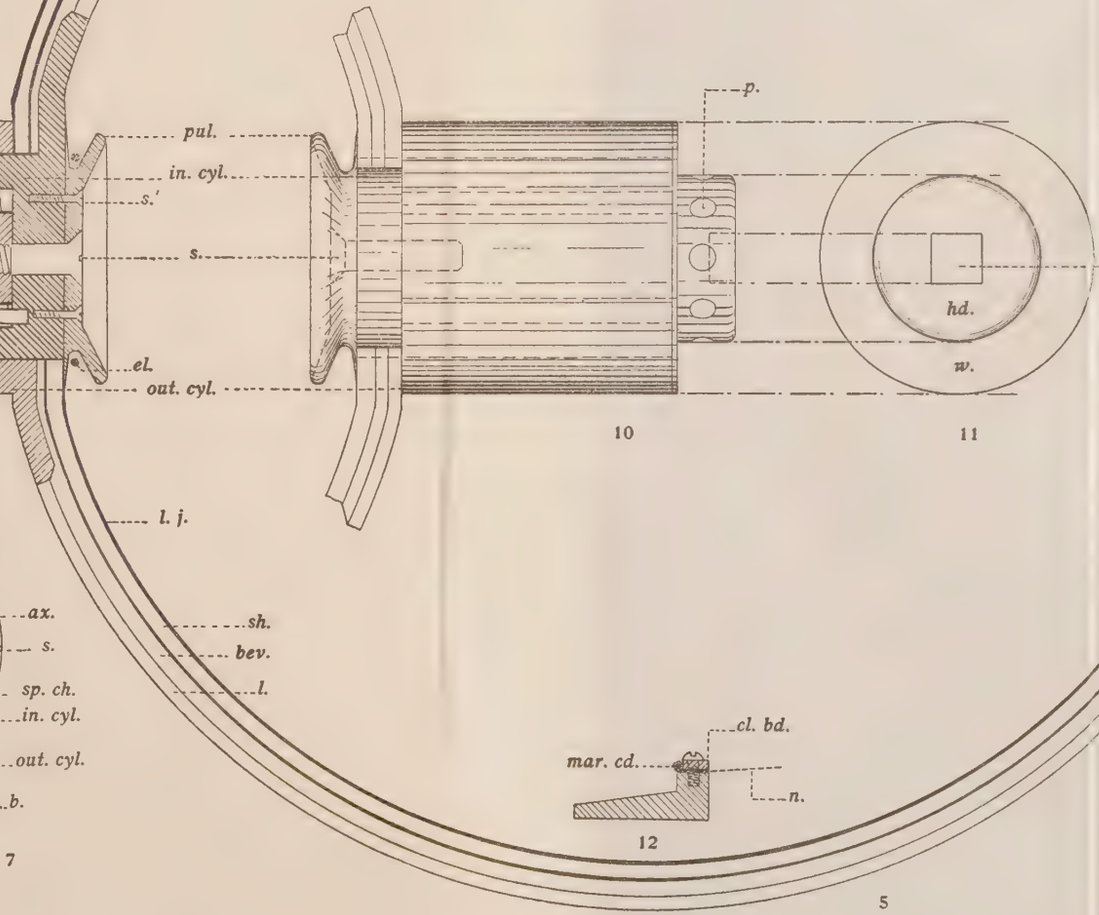

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PLATE 25

Fig. 14. Accumulator springs on the supporting arm for the net. × about ⅜.

Fig. 15. Diagram of top of head piece of net showing cable slot (*c. sl.*), cable bolt (*c. b.*), trips (tr^1, tr^2), buffers ($buf.^1$, $buf.^2$), thumb-bolt ($th.\ b.^1$) for releasing and setting cable bolt, set screw (*s. scr.*) for the slot filler (*sl. fil.*) and the rear lug (*lug*) for the net support (*n. sup.*) and accumulator carrier (*acc. sup.*). × ¼.

Fig. 16. Longitudinal section through plankton bucket showing head-piece (*hd. p.*), net clamp (*n. cl.*), silk window (*s. w.*) and closing plug (*pl.*). × ½.

ABBREVIATIONS

acc. sup.—accumulator supporter.
$buf.^1$, $buf.^2$—first and second buffers.
c.—cable.
c. b.—cable bolt.
c. sl.—cable slot.
cush.—cushion for accumulator.
dr. pt.—drip point of bucket.
fl.—flange of net clamp.
hd. p.—head-piece of net.
lug—lug for net support.
n. cl.—net clamp.
n. sup.—net supporter.
op.—opening in end of cable bolt.
pl.—plug of bucket.
r.—supporting rings of bucket.
s. scr.—set screw.
sh.—shoulder of supporter casting.
sl. fil.—slot filler.
sp. ch.—spring chamber.
str.—tie string for silk window.
s. w.—silk window.
$th.\ b.^1$, $th.\ b.^2$—two positions of thumb-bolt.
$tr.^1$, $tr.^2$—first and second trips.
w.—window in side of bucket.

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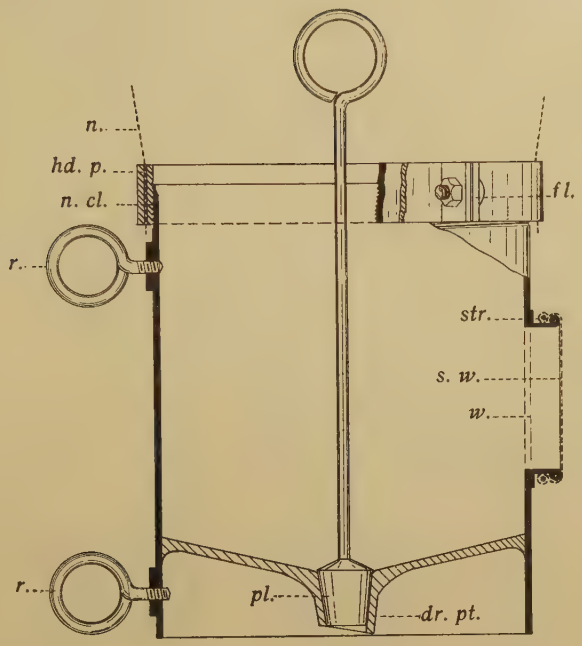
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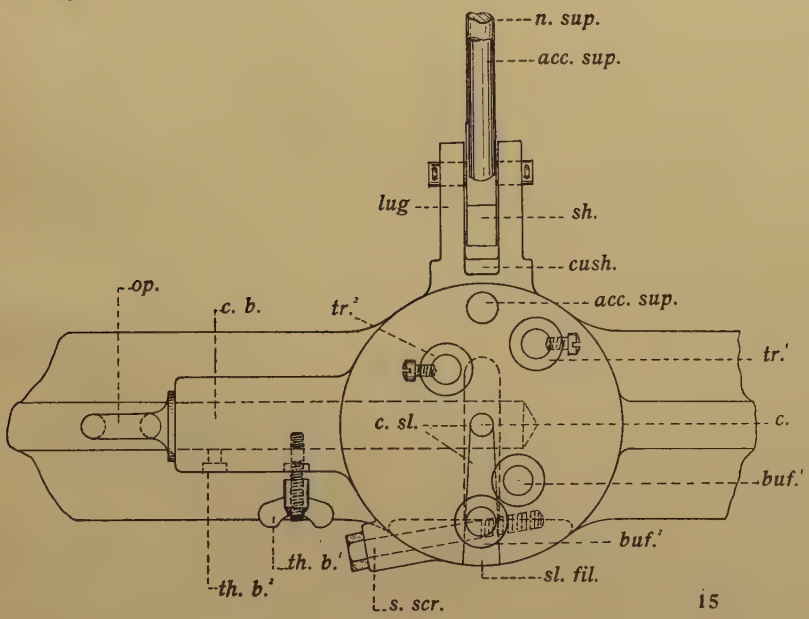
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sl. fil.
th. b.²
s. scr.

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UNIVERSITY OF CALIFORNIA PUBLICATIONS

IN

ZOOLOGY

Vol. 8, No. 9, pp. 349-352 November 18, 1911

ON AN IMPROVED FORM OF SELF-CLOSING WATER-BUCKET FOR PLANKTON INVESTIGATIONS

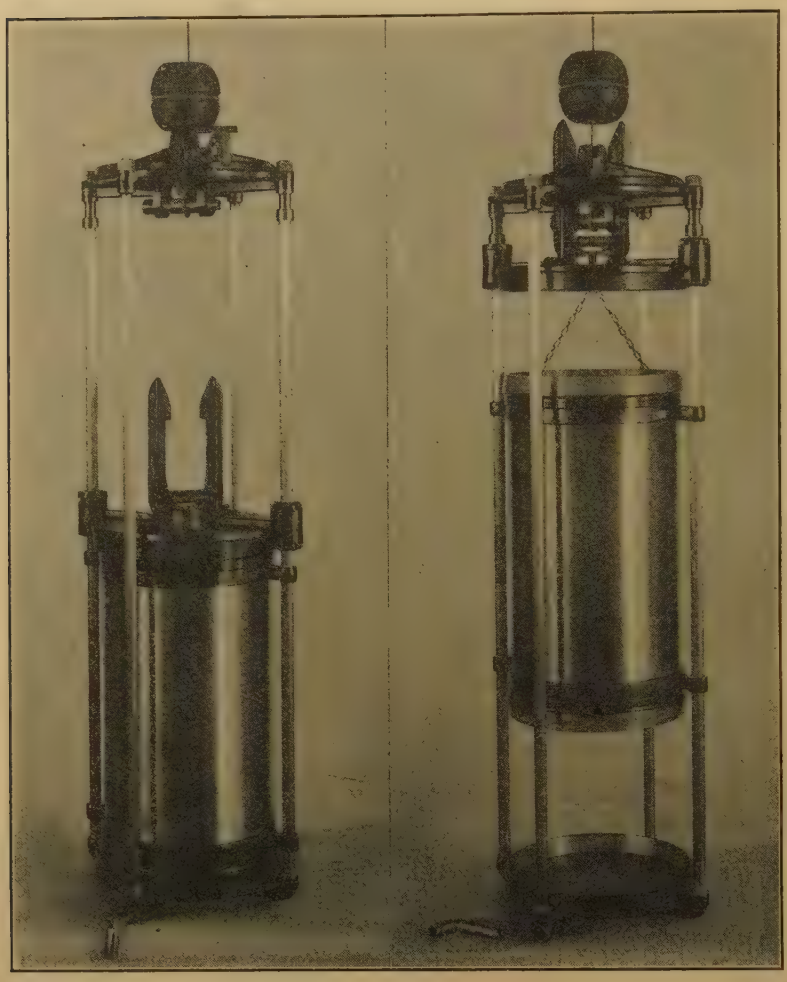
BY

CHARLES ATWOOD KOFOID

(Contribution from the Laboratory of the Marine Biological Association of San Diego)

An account of the water-bucket used in plankton investigations at the Biological Station at La Jolla, near San Diego, was published by me (1905) several years ago. This bucket has been used repeatedly in connection with various investigations (see McEwen, 1909) in progress at the station, and has worked very satisfactorily. Continued use and the accidents inevitable on shipboard have developed certain defects in construction which have been eliminated in a new model constructed for me by Mr. V. Arntzen, expert mechanician of the University of California, and placed in the exhibit of instruments for oceanographic research in the Musée Océanographique at Monaco, Principauté de Monaco, founded by S. A. S. Albert I, Prince of Monaco (see Kofoid, 1910). It is the purpose of this note to record these improvements.

In the first model the four standards (figs. A, B) connecting the brass castings which form the head and base, were made of heavy brass tubing 16 mm. in diameter. These proved too weak to stand the usage in handling the heavy load of water, and also gave trouble by slight dents which they received and which interfered with the smooth working of the sleeves upon the cylinder and lid that guide these parts to their seats in closure. Accordingly in the new model solid rods of hard brass were substituted.



B A

Fig. A. Self-closing water-bucket set for lowering, with lid and cylinder suspended by two clutches held in place by springs to the headpiece. Detachable messenger in descent just above the clutches. Key-faucet removed from outlet. × 1/10.

Fig. B. The bucket after closure, lid and cylinder held in place by snap locks in standards. Messenger resting on rubber buffer. The hinged arm with turn-button below (above in figure), which closes the slot through which the cable is passed to the axis of the apparatus, is withdrawn and thrown outward. The cable eye is shown on the steel bolt which carries the weight of the apparatus. Key-faucet in place for emptying the contents. × 1/10.

The bucket is lowered on the end of the cable to the desired depth with the cylinder and lid in the position shown in figure A. Then the spherical cast-iron weight which parts in two halves is tied about the cable and dropped upon the head of the bucket, releasing the two hooked clutches which suspend the lid, with the attached cylinder, to the head, and dropping them to the position shown in figure B. The lid is locked in place by spring catches in the standards, and twenty liters of water from any desired depth are thus secured.

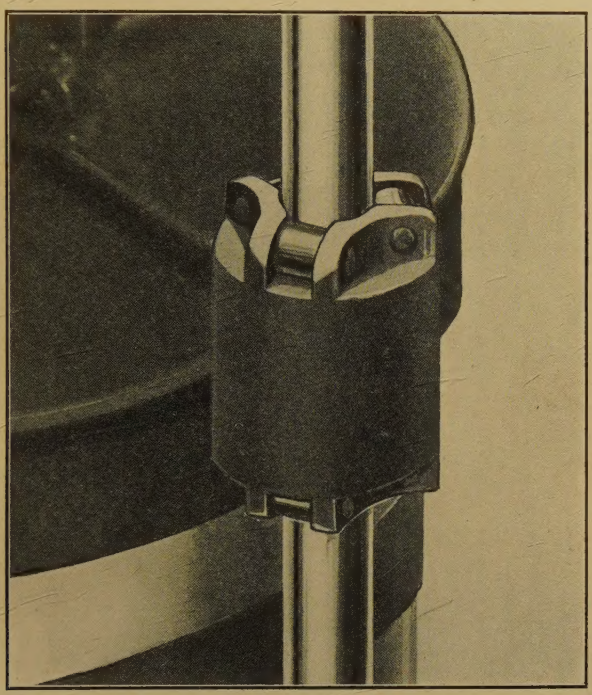


Fig. C. Sleeve of headpiece on standard, with steel rollers above and below. × ½.

In practice we found that slight unevenesses on the standards, or slight obliquities in the positions of lid and cylinder, led to one or both failing to close when released, because of this binding of the sleeves upon the standards. In the new model this defect has been obviated entirely by reconstructing the sleeves of the

lid. In place of the simple hub bored as a sleeve in the old model, the new model has a larger hub (fig. C), 40 mm. in diameter, with a bore rather greater than the standard in diameter and carrying between flanges on both the upper and lower surfaces of the hub three equidistant steel rollers 8 mm. in length and the same in diameter. These stand with their axis of revolution in the horizontal plane and in such a position that the least tilting of the lid in any direction brings one or more of them in contact with the standard, and their rolling motion facilitates the immediate descent of the lid.

The key-faucet and its revolving seat which closes the outlet, have both been constructed of bronze, which is more durable than the brass used in the first model, and the diameter of the outlet has been increased to hasten the emptying of the catch and thus to make possible more rapid repetition of catches at sea.

Zoological Laboratory, University of California.
Transmitted August 17, 1911.

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